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“Fishfinder”: Interactive Software Package to Predict Fish Locations Using Satellite Image Data and Fish Species Behavior Rules

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Using Satellite Image Data and Fish Species Behavior Rules**

ABSTRACT

A software program has been developed to aid in the prediction of fish location. Satellite and geophysical oceanographic databases have been assembled for the West coastal of the U.S. which are used to predict the locations of fish. A user interactive graphical interface written in Interactive Data Language, visually displays the databases and connects a series of fish rules by performing a logical and operations. The resultant bitmap is displays the intersection of the rules which are the locations of possible fish locations. The fish rules are still under in development. The software provides a real time interactive display for testing and developing an understanding of fish behavior.

I. INTRODUCTION

Predicting the locations of fish distributions has been a goal of a number of researchers for a number of years. Although this task is still mainly unsolved, Navy research programs are attempting to establish climatology and trends of fish distribution based on the coupling of large extensive environmental databases with a rule based fish behavior. Fish behavior based of critical environmental parameters is extremely difficult to develop since it requires extensive in situ measurements of fish catch statistics with the environmental properties. Remote sensing data can provide the extensive environmental ocean data both in real time and for climatology (Arnone et al 1993, Lemming and Herron 1986). These remote sensing applications for predicting fish distributions are being further explored. This research is presently underway, and preliminary tests have been performed on the Northern Anchovy and Albacore Tuna.

As an aid in formulating and understanding behavior rules and the environmental properties, a user interactive software development has been established to provide easy methods of interacting large environmental databases with fish rules. Through this method improved "rules" of behavior can be investigated and validated with fish catch statistics. This software has been named "FISHFINDER."

A software tool has been developed in Interactive Data Language (IDL) to perform a series of logical operations on oceanographic imagery based on fish behavior characteristics, to predict the probable locations of a specific fish population. "FISHFINDER" was developed to determine the locations of fish populations. "FISHFINDER" performs a logical "and" operation on the six input data files and outputs

an image data file as a bitmap representing locations where the fish-behavior rules have been successful.

Fish locations are important for Navy active acoustic systems because reverberation from fish bladders produce ambient noise, which degrades system performance. Pelagic fish swimbladders have a significant impact on the performance of low frequency active acoustic systems (Love 1990; Love and Hunger 1975). Swimbladders provide strong reflectors of acoustic energy and account for significant amounts of volume reverberation in the ocean. Acoustic models used to predict system performance require the distribution of fish. Therefore, predictions of the distribution of pelagic fish populations is required to improve Navy active acoustic system performance. From the distribution of the fish size, bladder size, school size, and water depth, acoustic models can provide an approximation of the volume reverberation that can be expected within a given area.

A major problem that presently faces the Navy is an estimate the locations of fish distributions; i.e., what are the temporal and spatial variability of the various species. Additionally, fish location software is important for defining probable fish densities for fishery industries. The oceanographic data used in this research were derived from a satellite image database, a bathymetric database, and the Generalized Digital Environmental Model (GDEM) climatological database.

The west coast of the U.S. was selected as a test area for the initial investigation because of the availability of historical fish catch data in this strategically important acoustic region. Additionally, Heceta Bank, a region off the Oregon coast will be the location of a experiment in the summer of 1995 in which the fish models and fish density predictions will be tested and validated.

The objective of this report is to describe the software and databases that are presently available in the "FISHFINDER" research program. Additional fish behavior rules are presently being developed and will the subject of follow-on documents.

II. OCEAN DATABASES

Oceanographic image databases, which are the inputs to "FISHFINDER," are listed below:

Parameter	Satellite/Data Source
1. Chlorophyll Pigment distribution	- Coastal Zone Color Scanner (CZCS)
2. Sea Surface Temperature (SST)	- (NOAA/AVHRR)
3. Pigment Gradient Field	- CZCS
4. SST gradient field	- AVHRR
5. Bathymetry	- Synbaps
6. GDEM subsurface temperature fields	- GDEM Climatology
7. MLD (Mixed Layer Depth)	- GDEM Climatology

The image database was created at two resolutions: a low-resolution 20.0-km product and a higher-resolution 1.0-km product. The oceanographic databases are in an image format representing 512 by 512 pixel arrays of a flat file. The 20-km database extends from 10° N to 55° N and from 101° W to 146° W representing a 0.087 °/pixel. The spatial area of the 1-km database covers from 42° N to 47.12° N and from 122.88° W to 128° W. The image files are all 8-bit grey-count values and the conversion of these data to geophysical units are provided below. The images are in PC-SeaPak file format (Firestone et al 1989; Arnone et al 1993) in which the header record is the first 512-byte record.

The database structure has been established at the Naval Research Laboratory (NRL), Remote Sensing Applications Branch using the Silicon Graphics Crimson. The Ocean Color SGI network has established the database permanently resident on the hard disk farm. The database is located on SGI named "csips" and can be reached via the "ocolor" user and change directory (cd) to:

```
/disks/csipsd1/FISHDB
+-----+
/hires          /lores
```

Approximately 150 files reside in each of the high-resolution (hires) and low-resolution (lores) directories. Appendix A lists the files in each of these directories.

The Chlorophyll pigment database was constructed from the CZCS satellite, which operated from 1978 to 1986. The data were processed using the Gordon et al. 1983 algorithm. The low-resolution data were spatially and temporally averaged into 20-km regions to product monthly averages of the chlorophyll pigment distribution (Feldman et al. 1989). This research has subsampled the global product to a 512 by 512 image of the west coast of the U.S. (Arnone et al. 1993). Furthermore, data from 1983 and 1986 presently in the database were used in order to compare with existing fish data for this time period.

The high-resolution satellite data represent data from the West Coast Time Series (Abbot et al. 1990). These data are 1-km spatial resolution from CZCS and AVHRR (Advanced Very High Resolution Radiometer) for individual scenes covering the eastern Pacific off the U.S. west coast in "tiles." A tile is 5.12° latitude x 5.12° longitude, MERCATOR mapped projected satellite scene produced at the full resolution of the sensor (nominally 1.0 km) in a 8-bit byte flat-file format.

These data represent 512- by 512-km region taken from tiles F, G, J, and K (Abbott et al. 1990), which are centered over the Heceta Bank off the Oregon coast (Crout et al. 1994). This area was selected because of the availability of fish data and is

the site of an ongoing acoustic experiment (Nero and Love, in preparation). The high-resolution database used by "FISHFINDER" was a merged product of tiles F, G, J, and K. The merged tile combined subsections from the other four into a new image with the high-resolution geographic previously mentioned.

The SST database also is available at low- (20 km) and high- (1 km) spatial resolution. The 20-km database was constructed from the NODS (NASA Ocean Data System) (Smith and Lassanyi, 1990) archives using the University of Miami/RSMAS gridded, weekly, interpolated multichannel SST global fields. The NODS database that resides at NRL covers the time period from October 1981 to December 1988. At this time only 1983 and 1986 data are part of the "FISHFINDER" database because initially only fish catch data were available for those years. This database covers the SST range of 0.12 - 31.0 C on a global scale. These image data are coincident in registration to the pigment image database.

Temperatures from a seasonal version of the GDEM database were rasterized at standard depths, resulting in 14 flat files, 1 for each standard depth for each season. Rasterization included reduction of the GDEM database from a one-half degree resolution to 20 km. The seasonal flat files were then interpolated to create monthly temperature files at each of the standard depths (i.e., 14 standard depth flat files for each month). This process was also repeated for a high-resolution research version of a seasonal, coastal GDEM database for the Heceta Bank region. The 5 minute resolution database was reduced to 1 km.

Seasonal MLDs were derived from the GDEM seasonal database assuming that the MLD is defined as the depth above the depth where the temperature at depth differs from the surface temperature by 0.05° C. The SST images were driven through the mixed layer and combined with the GDEM data to produce rasterized temperature values at standard depths in image format for a particular month and year.

The process of generating the new rasterized fields followed the following logic. The SST field becomes the raster field at the surface or zero depth. For each of the remaining depth files, each pixel within the original rasterized temperature field and the MLD field were compared. If the MLD for the pixel was the depth of the rasterized field or greater, then the SST value is substituted at that pixel and the next pixel is addressed. If the MLD is less than the depth of the rasterized file, then the temperature value at that depth remains. For any rasterized flat file that contains depths within the mixed layer, the SST is assigned to those depths and a new flat file is generated for that depth. Each rasterized flat file above the base of the mixed layer is subjected to this analysis. When the process is completed, the environment for April 1983 differs from that of April 1986 due to the SST input. Improvements could be made to these files using proper mixed layer models for the area and months in question.

Two bathymetry database files exist, one in the high-resolution and one in the low-resolution database subdirectories. These bathymetry data were created from the synpabs bathymetry data using the PC-SeaPac software (Firestone et al. 1989). These bathymetry files cover the same geographic projections as the respective image files and range from 0 to bottom in meters.

III. NOMENCLATURE FOR DATA FILE STRUCTURE

A. 20-km Database

The following comments apply to the formatting of the low-resolution database contained in this directory. The general format of the data is the following:

"YDMMMXXX.20k"

Y represents the year,

3 indicates 1983

6 indicates 1986

D indicates the type of data

g GDEM

t satellite temperature

c satellite chlorophyll

MMM represents the month

JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG,

SEP, OCT, NOV, DEC

XXX indicates the specific data type

if d=g XXX is depth in meters

000, 010, 020, 030, 050, 075, 100, 125, 150, 200, 250,
300, 400

if d=t XXX=SST for sea surface temperature

XXX=GRD for sea surface temperature gradient

if d=c XXX=CHL for chlorophyll or

XXX=GRD for chlorophyll gradient

20k indicates the database resolution (20 km)

The MLD data are only available seasonally. The file format is contained in the following format:

"XXX_mld.20k"

XXX represents the season,
SPR, SUM, AUT, WIN

_mld indicates that the file is a MLD file

20k indicates the file is low resolution (20 km)

The bathymetry file is contained in the following format.

"batXXX.20k"

bat indicates that the file contains bathymetry

XXX indicates the type of bathymetry file
XXX=000 bathymetry range 0 to bottom

The second file was generated to allow computation of distance away from the shelf break, which is one of the parameters required by the fish rules.

B. 1-km Database

"YDMMMXXX.1k"

Y represents the year,
3 indicates 1983

6 indicates 1986

D indicates the type of data

g GDEM

t satellite temperature

c satellite chlorophyll

MMM represents the month

APR, MAY, JUN, JUL, AUG, SEP

XXX indicates the specific data type

if d=g XXX is depth in meters

000, 010, 020, 030, 050, 075, 100, 125,
150, 200, 250, 300, 400

if d=t XX=date

X = m = morning pass
a = afternoon pass
if d=c XX=date
X = m morning pass

1k indicates the resolution of the database (1 km)

Examples of 1 km files available follow:

3gjun000.1k	1983 GDEM surface temperature for June
3gaug100.1k	1983 GDEM 100-m temperature for August
3tjun01m.1k	1983 AVHRR SST for June 1
3cjun02m.1k	1983 CZCS chlorophyll for June 2

No high-resolution SST or chlorophyll gradient files are currently available for inclusion in this database.

The MLD files are in the following format:

"XXX_mld.1k"

XXX represents the season
SPR, SUM, AUT, WIN
_mld indicates that the file is a MLD file
1k indicates the file is low resolution (1 km)

The MLD files follow:

SPR_MLD.1k
SUM_MLD.1k
AUT_MLD.1k
WIN_MLD.1k

The bathymetry file is contained in the following format:

"batXXX.1k"

bat indicates that the file contains bathymetry
XXX indicates the type of bathymetry file
XXX=000 bathymetry range from 0 to the bottom

1k indicates the file is high resolution (1 km)

The currently available bathymetry files follow:
bat000.1k

IV. GEOPHYSICAL UNIT CONVERSIONS

Equations for conversion of the image count values to geophysical values of temperature (TEM), chlorophyll pigment concentration (CHL), and depth (DEP) follow:

$$\text{TEM} = 0.125 * \text{COUNTS}$$

$$\text{CHL} = \text{INVLOG} (0.012 \text{ COUNTS} - 1.4)$$

$$\text{DEP} = (\text{Counts} * 23.931) - 22.931 \text{ (20-km database)}$$

$$\text{DEP} = (\text{Counts} * 15.559) - 14.559 \text{ (1-km database)}$$

In order to determine the count values from the geophysical values, the following equations apply:

$$\text{TCOUNTS} = \text{TEM} / 0.125$$

$$\text{CCOUNTS} = (\text{LOG CHL} + 1.4) / 0.012$$

$$\text{DCOUNTS} = (\text{DEP} + 22.913) / 23.913 \text{ (20 km database)}$$

$$\text{DCOUNTS} = (\text{DEP} + 14.559) / 15.559 \text{ (1 km database)}$$

V. HOW TO RUN "FISHFINDER"

1. logon to csips1.nrlssc.navy.mil using the "ocolor" account.
2. supply the requested password (Bob Arnone x.5268)
3. change directory to "fish," (/disks/csips1d1/ocolor/fish).
4. type; "gonefishing," this activates IDL.
5. at the IDL prompt type "fish/setup."

At this point, the first of two IDL widgets (Figure 1) are displayed for the user to input file names and to modify the gray ranges that correspond to the fish-behavior rules.

Prior to activating "gonefishing," it is suggested that the user/analyst open another Unix-shell and change directories to the specific low- or high-resolution database directory that is to be used. The user should then type, "pwd" and highlight the full directory pathname by using the left-mouse key. This highlighted entry can be used to supply the pathname with the specific image file name required in the set-up menus for "gonefishing." This technique speeds-up the input entry process considerably.

A. SETUP Fish Menu

Figure 1 shows the "SETUP" menu typically displayed for each of the oceanographic fields.

These include:

1. SST file -
2. Chlorophyll (CHL file)
3. Bathymetry - Bat
4. Mixed Layer Depth - MLD
5. Frontal Analyses 1 - FRT-1
6. Frontal Analyses 2 - FRT-2

The inputs from either high- or low-resolution databases are specified here. The user activates the "select file" button and inputs the required data files. Note the widget sliders underneath the "select file" key. These sliders can be adjusted in the full range of 0-255 count values. Prior to adjusting these sliders, the user must convert the chosen geophysical parameters of each input data field into a grey-count value (see conversion to geophysical units). After adjusting the sliders the user may save the present set-up as a file by activating "Save a Set-up" and later recalling these setup parameters by activating "Load a Setup." An example setup file can be retrieved from the "lores" subdirectory, and it is called "RUN2."

Note that for the frontal analyses (FRT1 and FRT2) that typically FRT1 uses the SST gradient data and FRT2 uses the CHL gradient data. However, different data sets can be applied to these frontal analyses. The minimum gradient slider selects a count value and everything greater than that value to activate. (For example, if a count value of 150 is selected, then all count values between 150 and 255 have been selected.) The Distance from front slider represents the number of pixels to use in a dilation. Therefore, if a distance of 2 is selected, and each pixel is 20 km, then the distance of 40 km on each side of the front is selected. A dilation is run on the previously selected gradient values. This generates a bit map of all locations within a distance from a selected gradient.

"Load Last Run" will recall from a disk file the last set of parameters automatically saved upon quitting a the latest session of "gonefishing".

Activating the "Continue" button opens the final menu and runs the logical operation on the data files.

B. MAIN Fish Menu

Figure 2 shows the User Interactive Fish Menu interface illustrating an example from the 20km database from May 1986. A image window is opened for each of the six input parameter files and is labeled accordingly for that data type. (Note however that any image data can be selected for any window.) The user has the opportunity again to use the sliders and perform any final adjustments to each data type or to reselect a different image data. The top four windows are all similar and display the image with the selected interval colored as the bit map. This colored area represents the locations where a fish rule is true for a certain parameter.

To change a selection:

1. Adjust the slider for the min and max values.
2. Select the Apply button.

or

1. Select the Options button at the bottom then select "Continuous" button
2. Adjust the slider for min max values. (The image bit will be applied continuously.)
3. 'BE PATIENT'

The sliders for the gradient field windows (bottom two on right) are different from the others in that this window will select a front of a certain geophysical unit and distances from that front. (Fish have been observed to occur within a certain distance from a front.) The gradient fields represent the SST or chlorophyll gradient from pixel to pixel with respect to latitude and longitude and are represented as small values (normally 1 - 20 grey counts). These counts represent geophysical units that must be converted in the same method that was described above. (For example, a SST count of 1 - 20 is a temperature of 0.1 to 2° C). The "Minimum Gradient" represents the minimum intensity of the front which you are looking at according to fish behavior rules. (For example, if we are looking for all fronts that are represented by a 2° temperature change, then we select the grey count of 20.)

The "Distance From Gradient" button specifies how many pixels from the gradient the user desires. This operation is performed by dilating the binary image by a certain number of pixels to create an binary image to use in the logical operation. If we are working with the low-resolution database, then the actual distance is computed by:

$$\text{No. of pixels} * 20 \text{ km} = \text{distance from front (km)}.$$

For the high-resolution database:

$$\text{No. of pixels} * 1 \text{ km} = \text{distance from the front (km)}.$$

Fish behavior rules are often stated in terms of fish being located at or near (kilometers) sites associated with specific gradient field. The gradient-field information allows the user to use this information in the logical comparison.

The large window on the bottom left represents the final fish prediction locations or the intersection of all the five window fish rules. The bit map represent the locations where all the rules are "true.". The bit map is overlaid on any of the image data. For example figure 2 shows the bit map overlaid on the SST data. The background data image is selected from the OPTIONS bottom at the bottom.

1. Data Window Options Button (5)

The "OPTIONS" key associated with each of the six data types provide the user with five additional options. These options are as follows:

1. ON/OFF toggle for the selected image/data window so it will not be used in the calculation.
2. Gang slider adjusts both the min/max values over a unspecified range so as you adjust either the min or max slider the other is shifted too.
3. UNGang slider allows the user to adjust the min/max sliders independently of each other. The user determines the overall range.
4. Select file allows the user to load a new file for a specific data type.
5. Colors allows the user to select one of nine colors to highlight the bit-map data range.

2. Six Bottom Buttons

The six bottom buttons along the bottom right are explained below.

1. QUIT exits "gonefishing" and returns the user to the IDL prompt.
2. Help is the on-line help-key but is not working at this time.
3. APPLY applies all the current settings of the sliders to the respective images and activates the logical operation.
4. OPTIONS allows the user to place one of the six data-type files into the larger display window. Several sub-options are located here but are not working at this time.
5. View allows the user to display the results of the logical operation in the larger window and be saved into a disk file. Also other files can be loaded through this option including earlier saved results for comparison. Several sub-options are located but are not working at this time.

6. Setup recalls the set-up menu options discussed earlier.

VI. CONCLUSIONS

Fish prediction software, which uses image geophysical data and fish rules to determine probable locations has been developed. The software represents an interactive user interface to test fish rules based on geophysical parameters. The software determines locations where up to five true fish rule conditions occur. This software will help to determine fish-rules based on user interaction. The image database used for this software has been assembled from satellite data, GDEM, and bathymetry at low-(20 km) and high-(1 km) spatial resolution for 1983 and 1986.

The "FISHFINDER" software is approximately 90% complete. Several option keys are available through the IDL widget, but have not been activated at this time until some user feedback is received regarding the potential usefulness of these options.

Future efforts include further validation and verification of the fish rules using the "FISHHUNTER" software. The software system will be used to predict fish locations to support field exercises. Modeling of the MLD for each season may be more realistic for determining the temperature structure for a month of a particular year. Additional effort is required to examine the MLD predictions and to define improved methods of coupling historical GDEM climatology with real time SST satellite data.

Additionally, the simple bit map (yes/no) prediction location will be expanded into a probability prediction location.

The fish rules are a major limitation in predicting fish locations. Fish rules are not always systematic and can be problematic in response to local conditions. In addition, delineating fish rules requires a substantial fish catch database with the corresponding geophysical parameters. Because of the limited fish location data, these fish rules selection have been difficult to obtain. Current efforts are to generate these rules from a "fish spotter" data.

The "FISHFINDER" package runs quickly and is an excellent tool for executing interactive logical operations simultaneously on multiple data sets. User feedback is required for any improvements to the software.

VII. ACKNOWLEDGMENTS

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APPENDIX A

Directory of the Databases

1-km Data

example:

/disks/csipsd1/FISHDB/hires

Protection	User	Owner	Size	Date Created	File Name
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug01m.1k
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug02m.1k
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug04m.1k
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug05m.1k
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug08m.1k
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug09m.1k
-rw-r--r--	1 ladner	NRL7240	262656	Oct 26 1993	3caug10m.1k
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APPENDIX Continued

Directory of the Databases

Low-Resolution Database 20-km Data

example:

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chl= chlorophyll

c=chlorophyll

20k = 20-km resolution

apr = april

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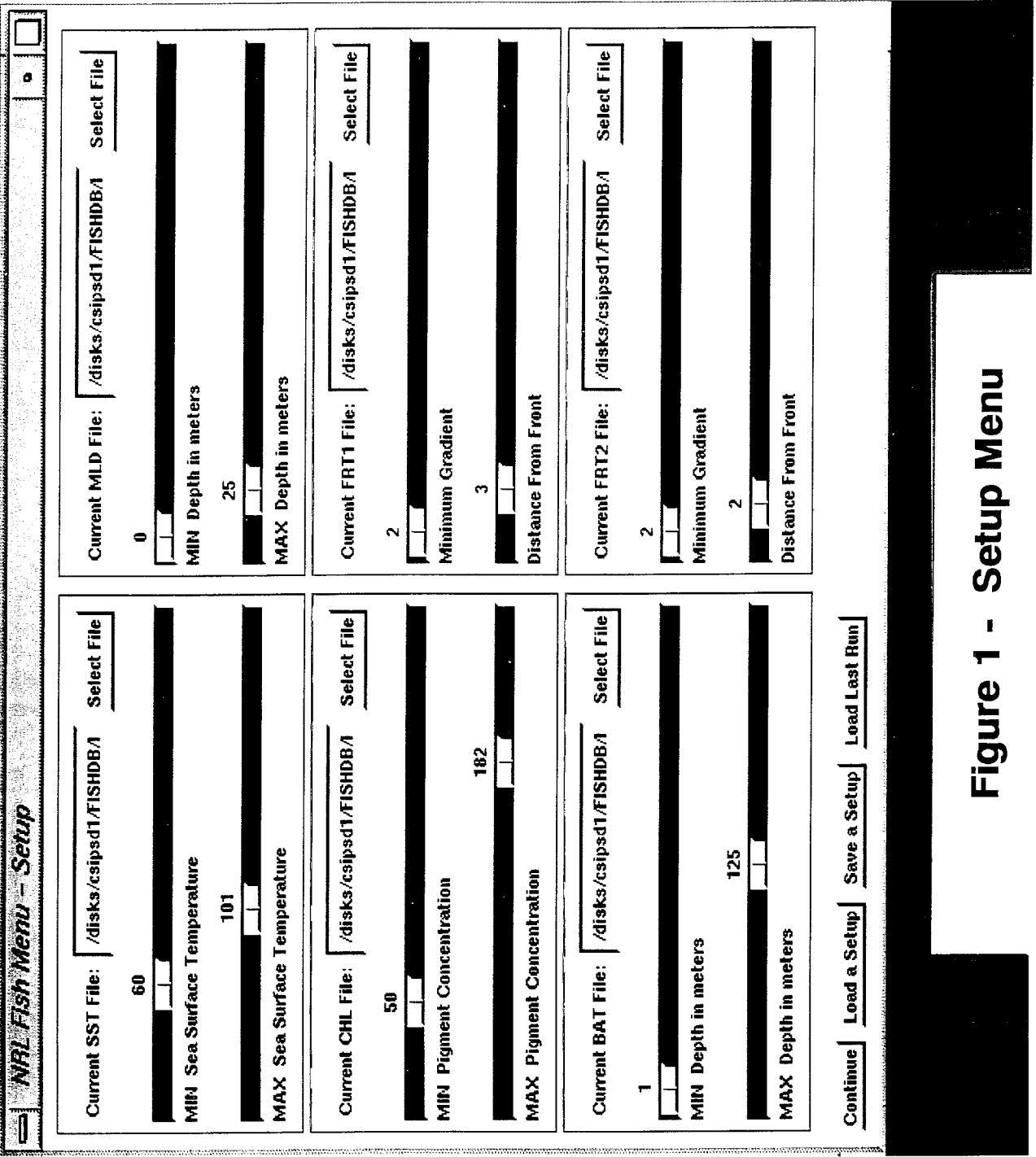


Figure 1 - Setup Menu

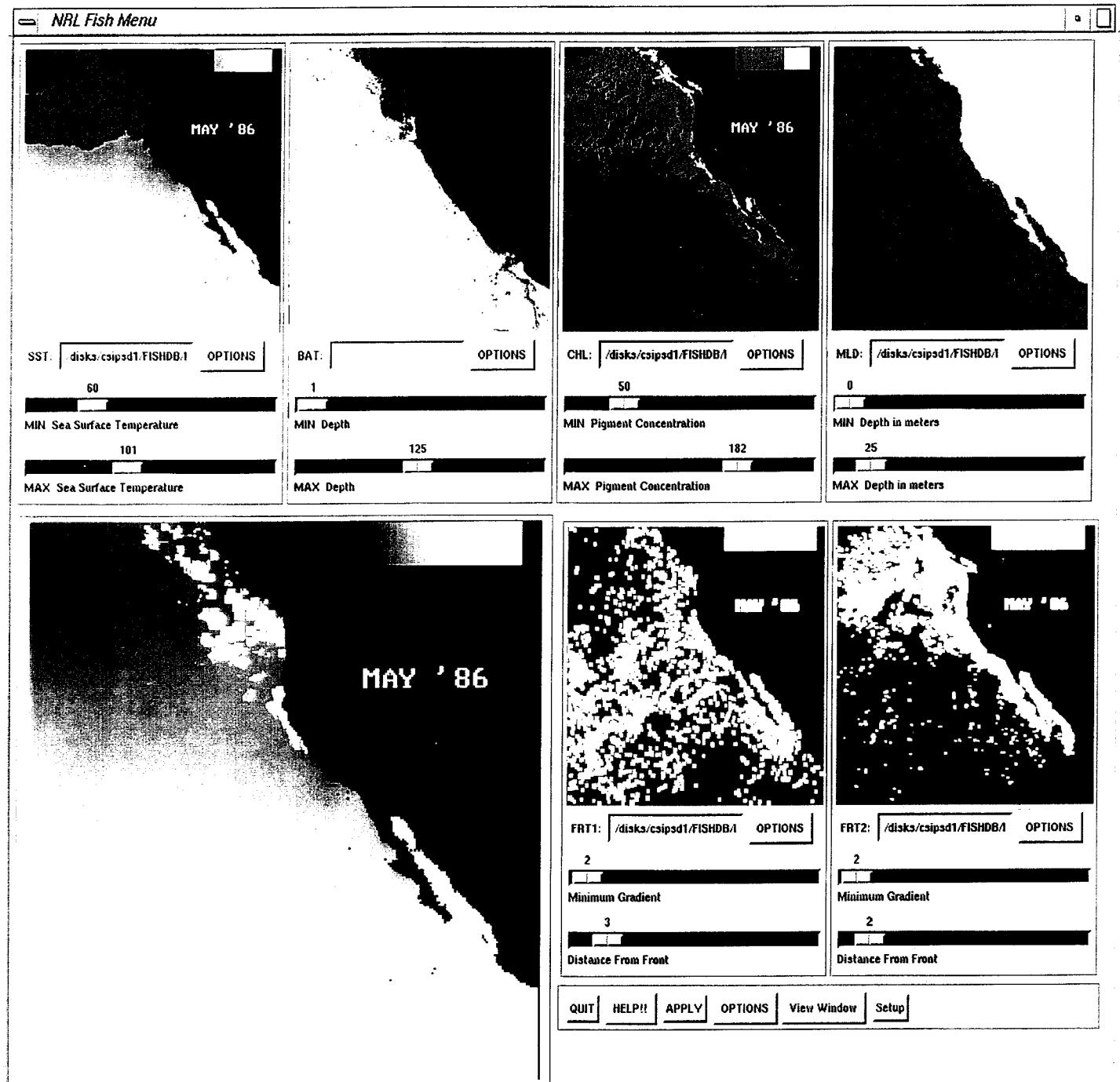


Figure 2 - Main Menu